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RECENT DEVELOPMENTS IN SHIP STABILIZATION ... ... **page 3**

By J. BELL M.Sc. M.I.E.E.

For many years various attempts have been made to counteract, if not eliminate entirely, the rolling of a ship. The gyro-stabilizer and the anti-rolling tank are well known but have not proved attractive either to shipowner or shipbuilder because of the space occupied, the weight, and the cost, apart from the fact that the efficacy of these devices is not established. No stabilizer of these types is known to have been fitted for a number of years.

The Denny-Brown system of stabilization, by using only small gyroscopes to control powerful stabilizing machinery, has provided a new approach to the problem. The first description of this equipment appeared in *Technique* Vol. 3 No. 2, but since then the control gear has been improved, and the system has been installed by many more vessels, including most cross-channel steamers. In this issue Mr J. Bell M.Sc. M.I.E.E., our Chief Research Engineer, who was primarily responsible for the design of the original control gear, brings the stabilizer story up to date.

THE FRONT COVER

The *Falaise* was the first of the British Railways' steamers to be fitted with the Denny-Brown stabilizer described in this issue of *Technique*. Though primarily a cross-channel steamer, the *Falaise* is regularly used for short cruises — a fact which testifies to the effectiveness of this method of stabilization.

A testing-switch on the bridge enables the captain to control the stabilizer fins by hand. The fins follow the motion of the switch, returning to zero immediately it is released. By operating this switch in synchronism with the natural rolling period of the ship, a roll may be built up in calm weather and then allowed to die down or be rapidly damped out by switching to normal gyro control. This provides a simple and convenient method of testing the stabilizer.

PHYSICAL SOCIETY EXHIBITION, 1955

At the 1955 Physical Society Exhibition, which is being held (for the first time) at the new Horticultural Hall, Vincent Square, Westminster, from 25th to 28th April inclusive, we shall be exhibiting the following instruments:

D-630 and D-639 Valve-Maintained Tuning Forks; D-694 Four-Stage Frequency Divider; D-695 Small Decade Oscillator; D-698 Weston Standard Cell; D-727 Wave Correlator; D-728 Impedance-Angle Meter; D-729 Phase Meter; Size 18 Synchros; Mk 8 Mod. 0 Servomotor; D-614 Servo Amplifier; D-696 Hydraulic Relay; D-649 18-inch Mufax Chart Recorder; D-658 18-inch Mufax Chart Transmitter.

MAGSLIP DATA SHEETS—AN APOLOGY

Since Magslip Data Sheets were first issued some months ago, we have received many requests for Publication E-1000, giving details of applications and typical Magslip chains. We regret that this booklet is not yet available, but we are delaying publication to make it more comprehensive than was originally contemplated.

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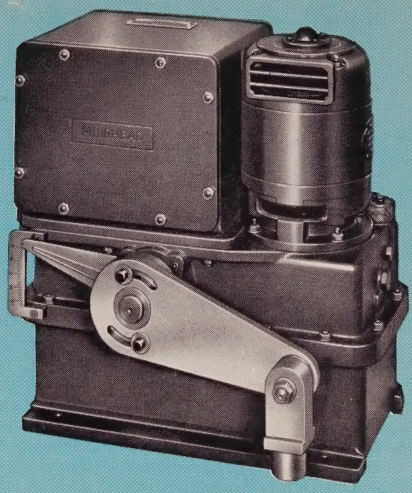
RECENT DEVELOPMENTS IN SHIP STABILIZATION

By J. Bell M.Sc. M.I.E.E. *



Hydraulic Relay Unit

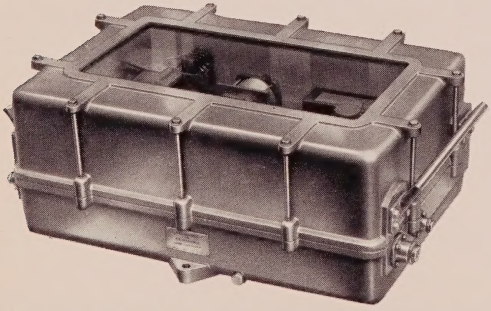
IT is over five years since an article on ship stabilization last appeared in this journal; the control gear then described is still supplied for this purpose. The ship stabilizer is being fitted in an increasing number of vessels, and in this article it is proposed to indicate the progress which has been made, and to deal with some more general points on stabilization which did not appear in the previous article.

A search in the Patents Office has revealed an interesting Patent, No. 19886, which was granted to Hiram S. Maxim in 1890, an extract from which is as follows:

'. . . My invention is designed to prevent the rolling and pitching of vessels at sea. . . . It would require a relatively small amount of force, if properly applied to the ship, to prevent or greatly diminish the rolling and pitching of the same. I accomplish the desired result in a convenient and advantageous manner by the employment of strong fins worked by hydraulic or other motor apparatus, the action of which is controlled by gravity or otherwise.'

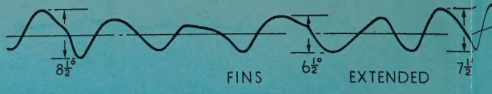
It is interesting that the earlier inventor refers also to the pitching of a vessel and that his patent covered this by providing an additional fin at the bow of the vessel. Pitch stabilization, however, is not so readily achieved as roll stabilization since the forces involved are of a different order. The righting moment of the vessel in the fore and aft direction is very great compared with the righting moment in the rolling direction and also the natural damping of the vessel in the pitch direction is considerable while that in the rolling direction is small. It appears from these considerations that the provision of pitch stabilization would require such large equipment to be installed in the vessel as to be uneconomic.

Messrs Denny & Brothers, in their Leven shipyard at Dumbarton, have devoted considerable energies to arriving at an optimum hydrodynamic solution for the stabilizer fins for anti-rolling, and Messrs Brown Brothers of Edinburgh have likewise devoted themselves to producing appropriate hydraulic machinery for operating the fins.



Control Unit with cover in position

* Chief Research Engineer, Muirhead & Co., Limited



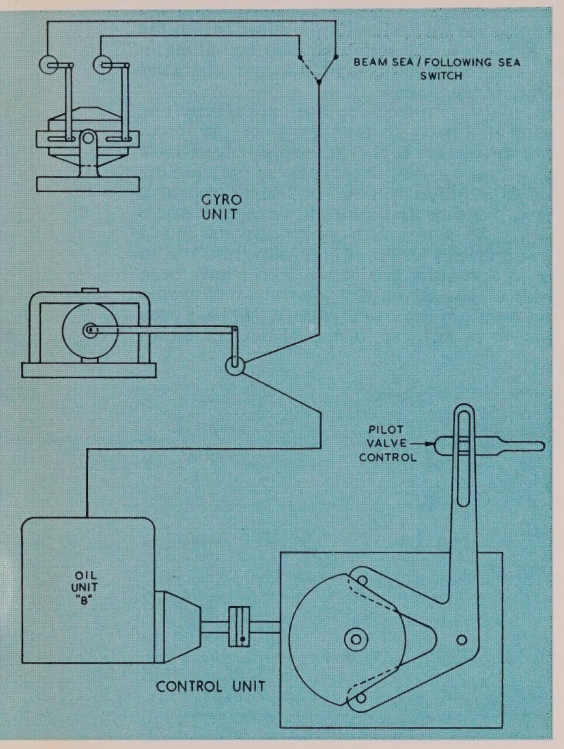


Fig. 1. Original Control

Experience has been gathered on some hundred naval vessels to date and approximately fifty merchant vessels, the latter ranging in size from cross-channel steamers to the largest liners — the *Queen Elizabeth* is at present being equipped.

IMPROVED CONTROL GEAR

For these vessels Muirhead's have supplied control gear substantially as described in *Technique*, April 1949, but recently it has been decided to introduce some improvements and bring the equipment up to date. For the purpose of describing the improvements in more detail the schematic diagram of the control gear which appeared in the earlier number of *Technique* is reproduced here (Fig. 1) and opposite, the modified schematic diagram (Fig. 2).

In principle, the gyroscopic control has not been altered, although detail improvements have been made and will be described below. The remaining part of the control gear is, however, completely altered.

The original Admiralty-designed 'B' type oil unit and the associated gear-box and cam have been replaced by a new hydraulic unit specially designed for the purpose. This hydraulic relay unit (Muirhead Type D-696-A) incorporates in its preliminary stages a duplicate of the sensitive relay of the 'B' type oil unit, which is followed by a pair of 'power' cylinders, the pistons of which operate the output lever for actuating the pilot valve of the stabilizer hydraulic engine.

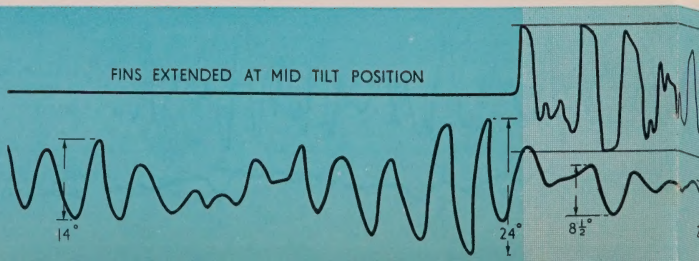
The force available is of the order of 60 lb and the stroke is $\pm 1\frac{1}{4}$ inches.

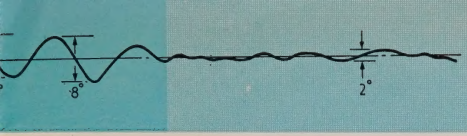
In the previous arrangement the 'B' type oil unit followed up precisely the sum of the total range of movements of the Magslips in the gyro unit and operated the cam to quite large angles when the ship movement was large. This rotational follow-up was obviously unnecessary since it was not available or required for actuation beyond the cam. With the new unit, only that part of the Magslip movements required for the proportional control of the fins is followed up. Additional movements of the Magslips in the controlling gyro unit still operate the Magslip in the hydraulic relay unit, but the sensitive valve actuated by this Magslip is arranged to have large freedom of movement at either end of the control region without a power follow-up.

(In a later issue of *Technique* the D-696-A hydraulic relay unit will be described in more detail, together with some indication of its performance and possible uses in fields other than ship stabilization).

As stated above, various detailed improvements have been made to the gyro unit. Adjustments of ratio between the gyros and the Magslips have been simplified by a redesign of the levers attached to the Magslips. Also, the vertical-keeping gyro has been fitted with a method of self-erection consisting of a pair of mercury switches and an electro-magnetic yoke and coil arrangement, similar to that used in certain Admiralty equipment. If the gyroscope is disturbed or started up in an attitude away from the vertical, it will seek the apparent (gravitational plus translational or centrifugal) vertical and be within $\pm\frac{1}{2}$ degree of its true position in less than five minutes. The units have been rehoused in a watertight cast aluminium case provided with appropriate glands, and fitted with a large inspection window in the cover.

FREE ROLLING





STABILIZING EQUIPMENT

The main stabilizing machinery and the fins, as previously mentioned, are not manufactured by Muirhead & Co., Limited. They are illustrated on pages 6 and 7. The illustration on page 6, based on details of actual equipment, shows an arrangement of fins fitted in a vessel. It will be seen that the end of the fin-box is welded to the hull and is adequately stiffened to withstand the pressure of the sea, the interior of the box being flooded when the ship is in commission. The fin operating and retracting gear is mounted on the frame at the end of each fin-box and is seen in actual detail on page 7. This is a reproduction of a photograph taken in the assembly shop at Messrs Brown Brothers, Edinburgh. The fin is shown in the fully retracted position, the operation of retraction being effected by means of the large horizontal ram. The tilt of the fin is derived from two vertical rams (one can be seen on the right) co-operating with a horizontal lever. The movement is transmitted to the fin by a second lever (shown in the foreground) coupled to the first by a hexagonal shaft which allows the fin to be operated 'inboard'. As the fin moves to the fully extended position this lever slides along the hexagonal shaft and engages with dogs on the tilt-actuating lever to provide the greater rigidity necessary for operation in the 'out' position at the vessel's rated speed.

The other illustration on page 7 shows a fin of the flap type projecting out of the side of the vessel; the diagrams show the tilting action of the fin in both directions. In the particular installation depicted arrangements have been made in the fin-box and in the shell plating of the vessel to give adequate clearance for the fin when operating to its maximum angles of tilt in either direction, whether retracted inboard to the vessel or not.

The shape of the cut-away section of the shell shows that the fin pivots near the point marked 'X' and also shows the additional clearance required for the movement of the flap at the tail of the fin. Fins of the flap type have a greater lift per unit area than fins without articulation. This point is important when dealing with fins which must be retracted, since the overall size governs the size of the fin-box, the total weight, and the amount of buoyancy lost due to flooded space inside the fin-box.

THE EFFECTIVENESS OF SHIP STABILIZATION

Two records are shown below, the upper being the fin movement and the lower the ship movement. By comparing that part of the record where there is no movement of the fins and the vessel is rolling freely with the other part of the record, where the stabilizer is in operation, a significant change of amplitude and character of rolling is apparent.

It is always difficult to compare strictly one period of time with another, since the forces being applied to the ship are necessarily variable and unknown, but experience in interpreting records indicates whether or not a reasonable comparison has been made. For example, where a roll of $8\frac{1}{2}$ degrees is recorded near the end of the stabilized portion, it is evident from the fin record that considerable sea forces have been acting on the vessel, and the roll which would have resulted at that time could easily have been equal to or in excess of the 24 degrees shown

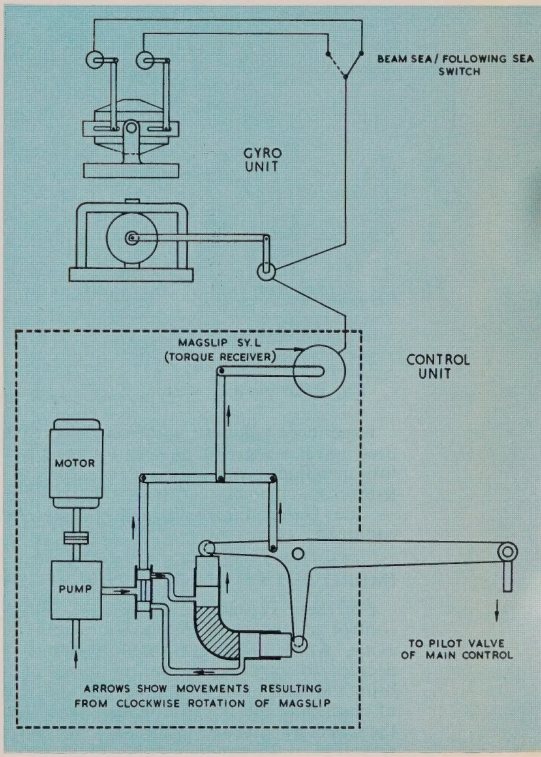
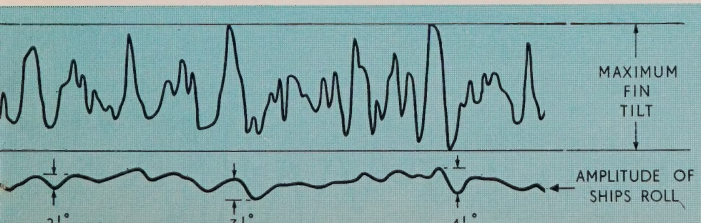
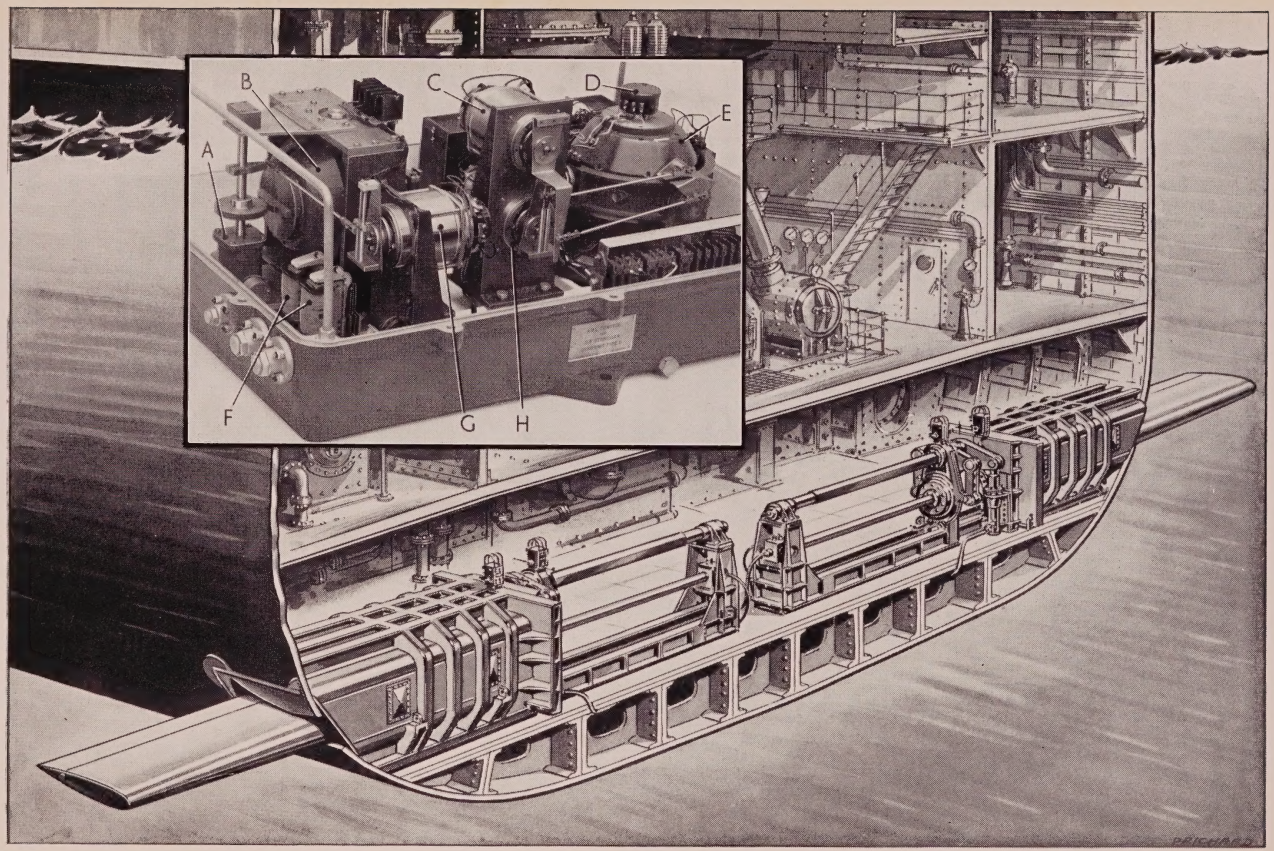


Fig. 2. Improved Control



STABILIZED



Typical arrangement of fins in a vessel

Index to gyro unit diagram (inset)

A Damping dashpot B Velocity gyro C Beam sea transmitter D Mercury switch E Vertical gyro

F Relays controlled from bridge G Velocity gyro follow-through transmitter H Following sea transmitter

early in the free rolling period. It is also noticeable that after the free rolling has built up to 24 degrees the decrement is comparatively slow, whereas after the stabilized roll of $8\frac{1}{2}$ degrees the vessel returns almost to an even keel as soon as the sea forces have been cancelled.

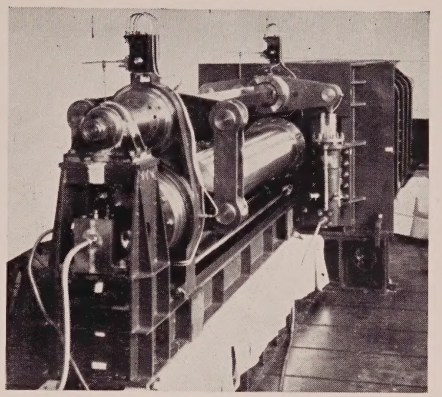
The effect of the stabilizer, as clearly indicated by this record, is to diminish the amplitude of rolling when large forces are acting on the vessel and to maintain the vessel within 2 or 3 degrees of its normal upright position when the forces of the sea are less than the control force available from the fins.

The record at the top of the centre pages shows the effect of stabilization on the *Oronsay*; this curve was taken under small sea conditions and indicates the difference between the ship motion under conditions of stabilization and free rolling. The fin record is not included.

Rolling of the order of ± 4 degrees is quite often encountered, and for the comfort of the passengers a reduction to ± 1 degree is generally very welcome. In this kind of sea, since the fin tilts required to provide the stabilizing torque are small, the drag on the vessel, reducing its forward motion, is almost negligible.

DOES STABILIZATION REDUCE SPEED?

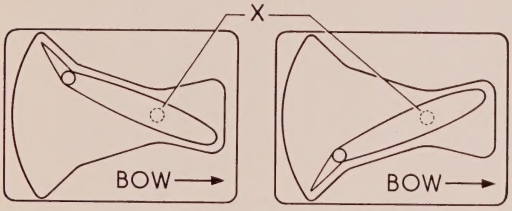
It is often asked how much the stabilizer affects the speed of a vessel and how much power is required to operate the equipment. It will be understood from the character of the installation, employing as it does fins reacting with the water, that the stabilizing torque is derived from the motion of the vessel through

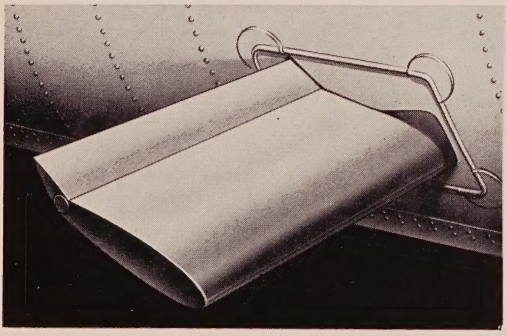


Fin operating and retracting mechanism

the water causing a 'lift' when the fin is inclined to the slipstream. Associated with the 'lift' of a fin there is also a 'drag'. The significance of the drag will depend in a given ship upon the size of the fins and the angle of tilt. When the angle of tilt is zero the drag can be very small, but when approaching the point of stall, the drag can approach quite a large figure, equal to about 25 per cent of the lift. The power therefore required to operate the equipment is derived from two sources; hydraulic machinery which effects the tilt, and the propulsive effort of the main engines of the vessel which overcomes the drag. The amount of power involved in the hydraulic operation for a medium-sized vessel is of the order of 30 h.p. but the maximum possible drag can run into much larger figures and may be equivalent to say, 20 per cent of the propulsive power. This latter figure, however, is the peak power and is only taken for short periods of time.

Examination of the rolling records, which depict fin-tilt as well as ship roll, shows that this peak power is taken for only 10 per cent of the total time of the period of stabilization recorded. The tilt of the fin more generally is in the neighbourhood of half (or less) of maximum and the drag is correspondingly less, due to the reduced angle. The operative drag can thus be regarded as an average figure derived from the integrated tilt-angle/time curve. It might easily be of the order of 8 or 10 per cent of the drag of the vessel when stabilizing in a rough sea, and any figure less than this, almost to zero, when stabilizing in a more gentle sea. Another factor enters into the problem, however, and that is the resistance of the vessel under rolling conditions. It is well known to naval architects and operators of vessels that when a vessel is rolling the resistance to the forward motion is considerably





Articulated fin projecting from vessel

greater than when it is upright. Since the stabilizer is functioning to prevent rolling, the increment of drag due to rolling is almost non-existent and this gain must be offset against the increased drag due to the operation of the fins. In practice it is found that in the average case the gain and the loss practically cancel out and it can be said, speaking generally, that the total amount of power required to drive a stabilized ship through the sea is almost identical with the amount of power to drive the same ship unstabilized. Experience has shown, however, that stabilization is a distinct advantage from the operator's point of view. A stabilized ship can be kept more correctly to its time schedule, since it can be steamed faster through a rough sea with the same degree of stress on the vessel.

VESSELS ALREADY EQUIPPED

Among the well-known vessels already fitted with this type of stabilizer are the following:

The Royal Yacht Britannia
Bergen Steamship Co.
T.S.S. *Leda* and *Venus*
British & Irish Steam Packet Co.
T.S.M.V. *Innisfallen*
British Transport Commission
T.S.S. *Falaise*, *Maid of Orleans*, and *Lord Warden*
Cunard White Star Co.
T.S.S. *Media* and *Saxonia*
Orient Steam Navigation Co.
T.S.S. *Oronsay*
P & O Steam Navigation Co.
T.S.S. *Chusan* and *Arcadia*

Equipment for 25 more vessels has been ordered.

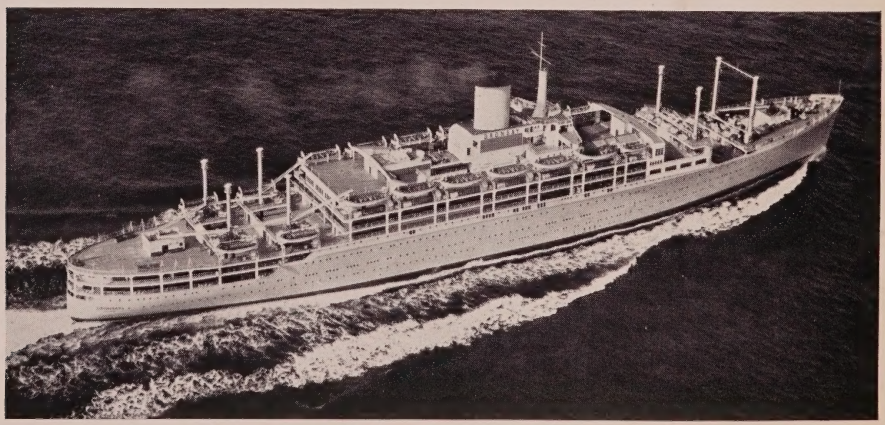
While practically all the vessels fitted so far have retractable fins, which in the operating position project a few feet outside the hull, at least one installation employs a large number of non-retractable fins projecting about the same amount as the bilge-keel. Some loss in hydrodynamic efficiency generally results from such an arrangement and multiple operating units, each of smaller size, have to be provided, but the space taken up in the vessel and also the loss of buoyancy are less.

For a given class of vessel each installation must be considered on its merits, but experience indicates that there may be a good case for non-retractable fins in the smallest installations as well as in larger vessels; in the very largest vessels multiple fins, whether of the retractable or non-retractable type, appear to be necessary in order to obtain the requisite stabilizing torque.

An unusual application of the ship stabilizer —and one which may appear at first sight rather unnecessary — is its installation on an ice-breaker for the Canadian service.

An ice-breaker functions by driving itself up on to the ice, and its contours must therefore be smooth. For this reason it cannot carry the bilge-keels fitted to other vessels as the normal protection against rolling. When in the open sea, going to and from its ice-breaking duties, the ship is most uncomfortable, as the roll damping is almost negligible. A relatively small installation of activated fins cuts down enormously the free rolling of such a vessel and makes it practicable for the crew to man the vessel adequately during its journeys. Obviously stabilization is not necessary when the ice is being broken, nor indeed could fins project from the hull during this operation since they would be broken off.

As already stated, the control gear now being supplied is substantially that designed during the war period, but recent experimental work and computation have indicated that a further improvement in the stabilizer control gear can be effected. This work is in hand and the results will be applied to the new stabilizers as soon as possible. The additional factor being taken into account is the rolling acceleration of the vessel suitably combined with the controls at present in use, and it appears practicable, without increasing the size of the main stabilizing equipment or fins, to effect a definite improvement both for light and heavy rolling conditions.



T.S.S. *Oronsay* on her trials

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